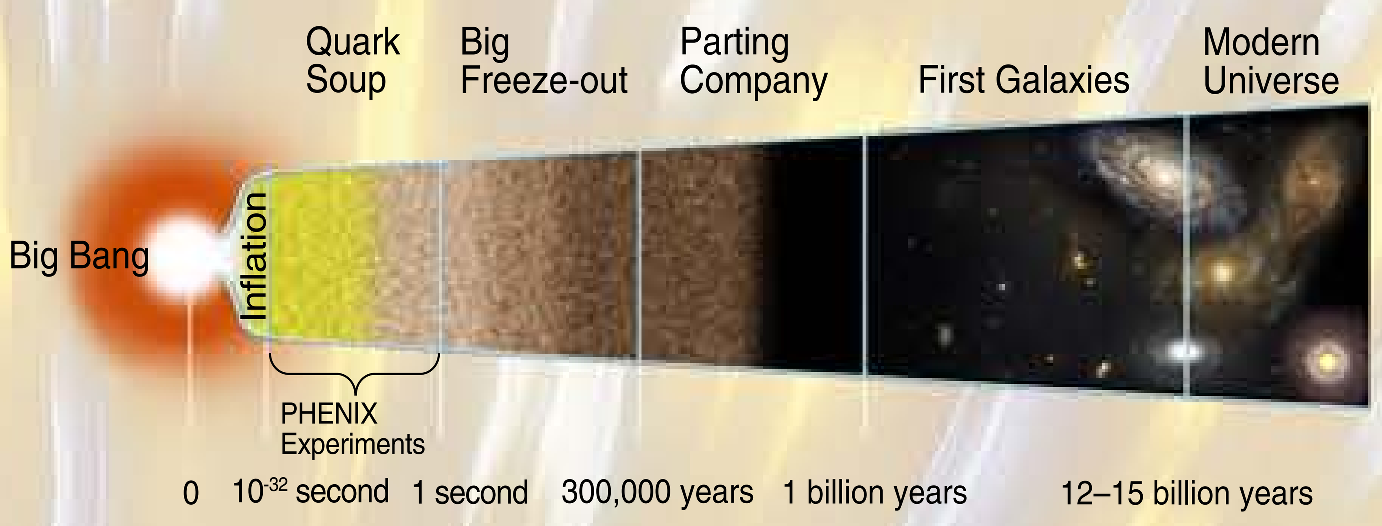
PHENIX: The Search for a New State of Matter

Our universe was born in a fraction of a second as a powerful explosion, a "Big Bang," filled all of space with a multitude of particles. The temperature of the universe in the first few microseconds of its existence was so high that even the components of atomic nuclei, protons and neutrons, could not be held together. Scientists believe that, during this early stage, the universe consisted of a plasma of truly elementary particles: quarks, the fundamental building blocks of protons and neutrons, and gluons, particles that bind quarks together. As this quark-gluon plasma (QGP) expanded and cooled over time, the quarks and gluons condensed to form protons and neutrons that are part of ordinary matter today. The QGP is the object of an intense study by an international scientific community at the Relativistic Heavy-Ion Collider (RHIC) at Brookhaven National Laboratory. One of the goals of this study is to mimic the conditions that existed during the first few microseconds after the Big Bang by attempting to produce a QGP in an experimental apparatus known as PHENIX.

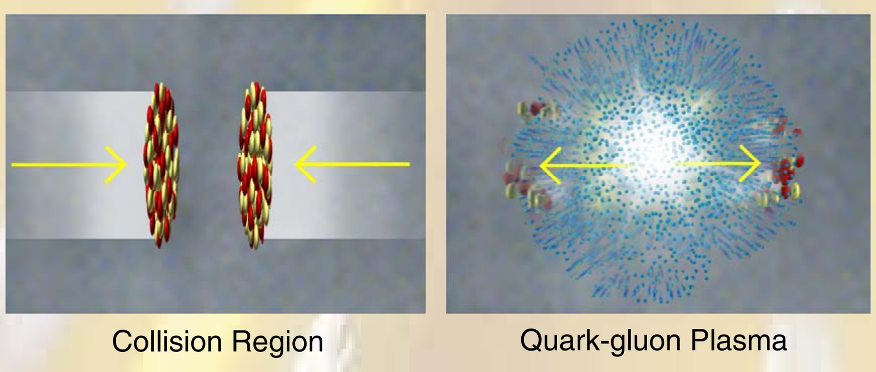


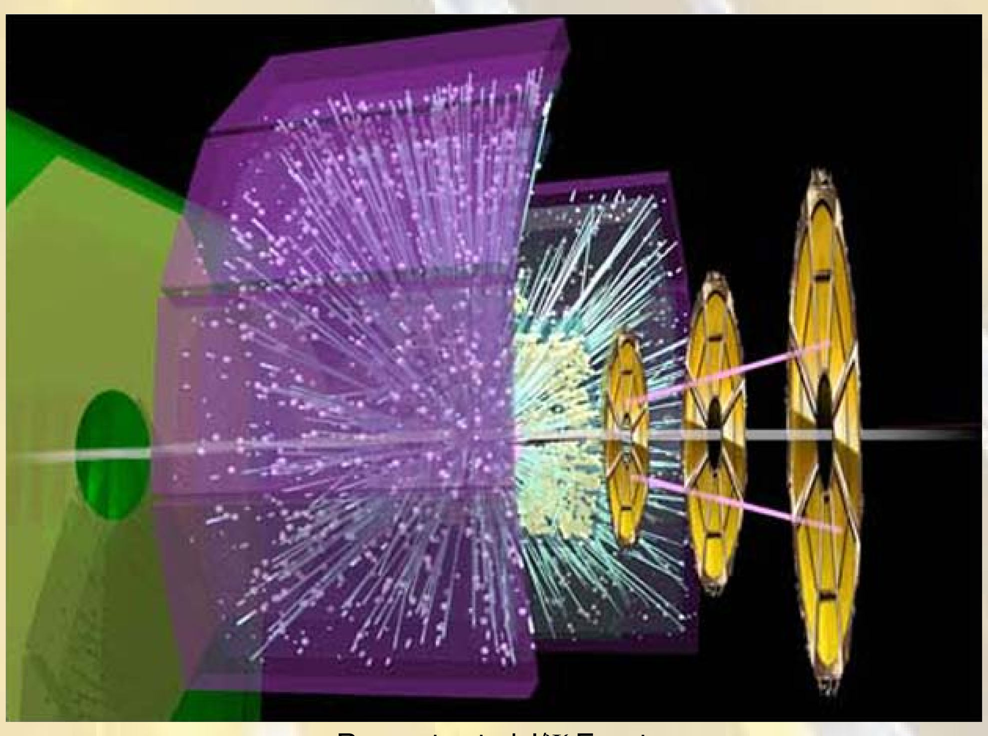
This illustration shows the time evolution of the Big Bang.

The RHIC complex accelerates gold ions to nearly the speed of light. When two gold ions collide head on, the temperature produced is higher than at the sun's center and, for a fleeting moment, thought to be sufficient to form a QGP. The PHENIX detector records the particles produced during these little Big Bangs and searches for clues of QGP formation. Staff members from the Physics Division designed and constructed three of the PHENIX detector systems—a multiplicity vertex detector (MVD) and two muon spectrometers—which are currently looking for distinct signatures of a QGP. One such signature would be the diminished production of the J/Ψ— a particle consisting of a charm (c) and an anti-charm ($\bar{c}$) quark.

The PHENIX Detector

Gold-Gold Ion Collision

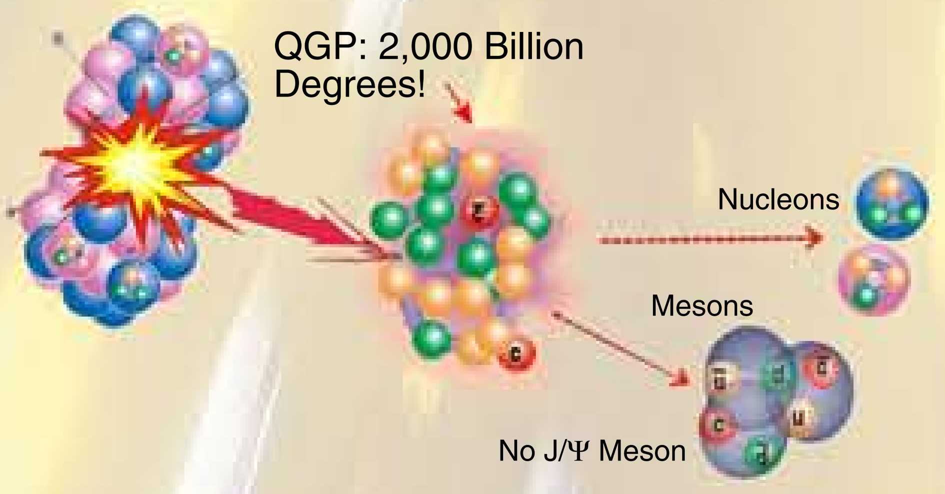


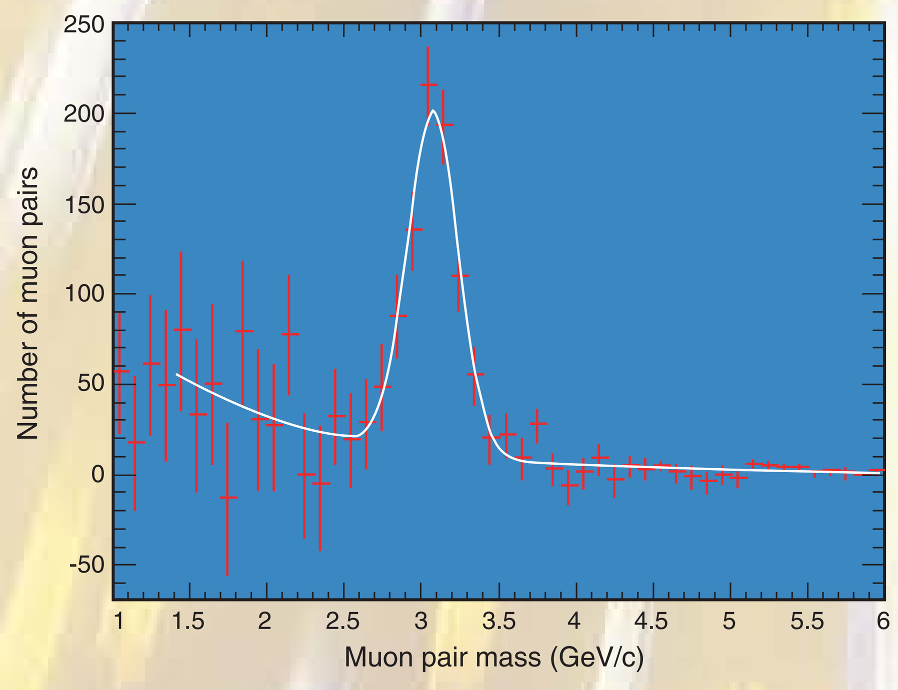


Reconstructed J/Ψ Event

These three images show the time evolution of a gold-gold (ion) collision and tracks from a reconstructed gold-gold collision. The first two frames show the gold ions colliding, and the third frame shows all the tracks of the event that can be seen by the central (purple) detectors, as well as two tracks from a candidate J/Ψ event in the muon arm region.

A Possible QGP Signature





In nuclear collisions (left), c and $\bar{c}$ quarks are sometimes formed. In ordinary nuclear environments, these often pair up to form J/Ψ particles. In a QGP (center), however, the abundance of other free quarks might screen them from each other. In this case, the charm quarks pair up with the more common up or down quarks to form so-called D mesons (bottom right) and thus J/Ψ particles will be strongly suppressed. A fraction of those particles decay into muon pairs. By observing the muon pairs, physicists can reconstruct J/Ψ events.

The plot is a measured mass spectrum (zoomed in on the J/Ψ peak) obtained from recent deuteron-gold ion collision data. The deuteron-gold collisions, where no excessive suppression of J/Ψ particles is expected, are used as a control experiment for the gold-gold collision experiments. Physics Division scientists have now established a baseline for J/Ψ production at RHIC and are currently analyzing data to measure the J/Ψ yield in gold-gold collisions.

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